(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification[7]:   B64D 15/22

(21) International Application Number: PCT/US01/25691

(22) International Filing Date: 16 August 2001 (16.08.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/641,298   18 August 2000 (18.08.2000)   US

(71) Applicant: ROSEMOUNT AEROSPACE INC.
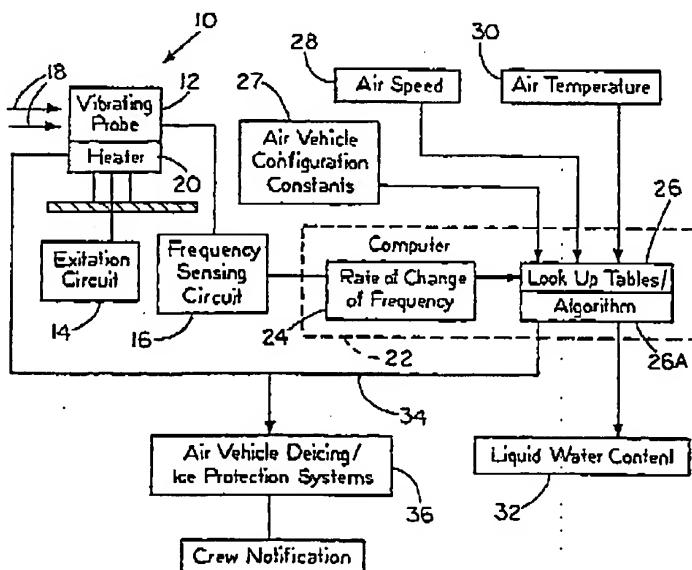[US/US]; 14300 Judicial Road, Burnsville, MN 55306 (US).

(72) Inventors: SEVERSON, John, A.; 883 Basswood Lane, Eagan, MN 55123 (US). SCHRAM, Kenneth, J.; 9654 Hampshire Lane, Eden Prairie, MN 55347 (US).

(74) Agents: WESTMAN, Nickolas, E. et al.; Westman, Champlin & Kelly, P.A., Suite 1600 - International Centre, 900 Second Avenue South, Minneapolis, MN 55402-3319 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report

[Continued on next page]

(54) Title: LIQUID WATER CONTENT MEASUREMENT APPARATUS AND METHOD

(57) Abstract: Ice accretion on a probe (12) is detected by determining the change of frequency of a vibrating type ice detector or sensor (14, 16) as ice starts to build up. The rate of change of frequency is determined (24) and is combined with parameters including air velocity (28) and air temperature (30) for providing a signal that indicates liquid water content in the airflow as well as ice accretion on the ice detector (14, 16).

WO 02/16201 A1

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

-1-

LIQUID WATER CONTENT MEASUREMENT
APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

The present invention relates to an
5 apparatus and method for determining with accuracy the
liquid water content of ambient air, particularly in
relation to air flows across air vehicles or other
structures.   The accurate and timely measurement of
liquid water content (LWC) permits prompt signalling
10 for activating deicing systems, and also permits
sensing atmospheric conditions for reporting or
research purposes.

Unheated bodies exposed to airflow laden
with supercooled water droplets will typically accrete
15 ice as the droplets impact the body and freeze. Icing
is particularly a problem with air vehicles.
Determining when ice is starting to form or predicting
when it will form is important in aircraft management
of deicing equipment including heaters, which can
20 consume huge amounts of power.   When the air
temperature is cold enough, 100% of the droplets
carried in the airflow will freeze.   If the
temperature warms or airflow is increased, the energy
balance relationship is altered.   A critical liquid
25 water content (LWC) is reached where not all of the
impinging supercooled water droplets freeze.   This
critical LWC is defined as the Ludlam Limit.   The
Ludlam Limit is described in an article by F.H. Ludlam
entitled The Heat Economy of a Rimed Cylinder. Quart.
30 J. Roy. Met. Soc., Vol. 77, 1951, pp. 663-666.
Additional descriptions of the problem are in articles
by B.L. Messinger, entitled Equilibrium Temperature of
an Unheated Icing Surface as a Function of Air Speed,

-2-

Journal of the Aeronautical Sciences, January 1953,
and a further article entitled _An Appraisal of The
Single Rotating Cylinder Method of Liquid Water
Content Measurement_, by J.R. Stallbrass, Report - Low
5   Temperature Laboratory No. LTR-LT-92, National
Research Council, Canada, 1978.

It has been shown that if the LWC increases
above the Ludlam Limit, the accretion characteristics
in theory remain unchanged, because excess water
10   simply blows off or runs off, rather than freezing.
Thus, present systems for determining liquid water
content based on ice accretion suffer degraded
accuracy above the Ludlam Limit. The Ludlam Limit for
a given temperature and airflow is the liquid water
15   content above which not all of the water freezes on
impact with an accreting surface.

Accretion based ice detectors are frequently
designed with probes that permit ice build up to a set
mass, perhaps taking 30 to 60 seconds depending on
20   conditions, at which time the presence of ice is
enunciated or indicated, and a probe heater energized
to melt the ice. Such ice detectors are well known in
the art, and many depend upon a vibrating sensor or
probe, with a frequency sensitive circuit set to
25   determine frequency changes caused by ice accreting on
the detector probe.

LWC can be roughly determined by monitoring
a signal proportional to the probe icing rate, which
again can be determined with existing circuitry, but
30   accuracy degrades rapidly if the LWC is above the
Ludlam Limit, because a portion of the impinging water
never freezes. In such cases the actual LWC will be
under reported, with the Ludlam Limit LWC being the

-3-

maximum that will be reported. Even though the droplet cloud may contain additional liquid water, there will be no indication from such an ice detector that there is additional liquid water in the air flow.
5   Thus, the prior art devices will not discern the actual liquid water content when the Ludlam Limit has been exceeded.

SUMMARY OF THE INVENTION

The present invention relates to determining
10   the liquid water content (LWC) in an airflow, in particular, air flow past an air data sensing probe on an air vehicle. The amount of the liquid water in the airflow is determined even for liquid water content levels above the Ludlam Limit. The present invention
15   senses ice growth rate on a vibrating probe type ice detector. The ice growth rate is predictably variable over an accretion cycle based upon the incremental rate of change of the vibrating probe's frequency throughout the sensing cycle. The rate of change of
20   probe vibration frequency (df/dt) throughout the ice accretion cycle is determined. Further, the rate of frequency change (df/dt) characteristics are demonstrated to be a predictable function of liquid water content, even above the Ludlam Limit, meaning
25   that LWC can be determined at the higher liquid water content level.

The rate of change of probe vibrating frequency is determined for all or a portion of the ice accretion phase of the probe operating cycle,
30   because it has been determined that this rate of frequency change (df/dt) is a function of LWC at that time.

In order to measure liquid water content

-4-

with the present invention, the air speed and the temperature of the ambient air must be known. These basic parameters are readily available from an air data computer, using outside instrumentation, such as

5　a pitot tube or a pitot-static tube, and a temperature sensor, such as a total air temperature sensor. The known liquid water content at a particular known air speed, temperature and rate of change of the vibration frequency of a vibrating probe ice detector are

10　determined and combined in a look up table. The values can be determined by actual icing wind tunnel tests, or test results can be used to derive an algorithm that provides liquid water content when the three variables, air flow rate (or air speed),

15　temperature and rate of change of frequency of vibration caused by ice accretion are known. Although a frequency rate of change is described herein, the rate of change of other signals sensitive to ice accretion could be used. A signal based on the rate

20　of change of ice accretion (but not merely the amount of ice accretion) is a key to proper results.

The overall accretion time has been found to decrease with increasing liquid water content in most cases, but this is not assured. This invention is

25　dependent on ice accretion, and will approach some limit of usefulness when operating conditions are such that little or no ice accretes on the probe. This may occur under conditions of warmer air temperature and high aerodynamic heating, for example.

30　　　BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram of the apparatus used for determining liquid water content (LWC) in response to rate of change of frequency

-5-

caused by commencement of ice accretion on a vibrating probe and for controlling probe heater deicers;

Figure 2 is a plot of measured rate of change or frequency during ice accretion at -5°C temperature, with a constant air speed of 200 knots with airflows having three different, but known levels of liquid water content in the air flow;

Figure 3 is a plot similar to Figure 2 with the indications taken at -10°C and a constant air speed of 200 knots with the same liquid water content in the airflows;

Figure 4 is a plot of rate of change of frequency during ice accretion of a typical vibrating probe at -5°C and a speed of 100 knots; and

Figure 5 is a composite plot of points derived as an average of several rate of change of frequency values (df/dt) of a test probe as a function of liquid water content at different air speeds and temperatures.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Figure 1 illustrates a typical set up for utilization of an existing ice detecting probe and the circuitry for determining liquid water content (LWC) even above the Ludlam Limit. The apparatus 10 includes a vibrating ice collecting or detector probe 12, such as that sold by Rosemount Aerospace Inc., Burnsville, Minnesota, as its Model 0871 series. An early vibrating, resonant frequency ice detector probe is shown in U.S. Patent No. 3,341,835 to F.D. Werner et al. In the present invention, an excitation circuit 14 is used for providing an excitation signal to vibrate the vibrating probe at a resonant frequency. A known frequency sensing circuit 16 is

-6-

utilized for determining changes of frequency of the
vibrating ice detector probe in a conventional manner.
The change in frequency is caused by ice accretion on
the surface of the ice detector probe. This design is
5   recognized to be insensitive to probe contaminants
such as dirt and insects. The rate of accretion of
ice is reflected in the rate of change of frequency.
The rate of ice accretion is directly related to the
liquid water content of the air. The probe 12 is
10   exposed to airflow as indicated by the arrows 18, and
supercooled water droplets will impact and freeze on
the probe 12 surface or previously accreted ice at
surface temperatures below freezing. The signal 34
indicating ice formation can be used for turning on
15   deicing equipment 36 or other ice protection systems
for the air vehicle involved and/or notifying the crew
of an icing condition. The signal 34 indicating ice
formation can be tailored to the particular air
vehicle and its level of tolerance for ice buildup,
20   such that deicing equipment is activated in a timely
manner, while nuisance activations are minimized.
The look up tables 26 or algorithm 26A are
designed to determine an icing severity level. After
a predetermined duration of exposure at a particular
25   icing condition constituting an icing severity level,
or an aggregate of conditions resulting in equivalent
ice buildup or impact to the aircraft, the signal 34
is supplied. The signal may be supplied continually
or on a periodic basis until the icing condition
30   abates. The calculated df/dt value changes and
provides the indication of ice formation, and when
correlated to airspeed and temperature is used as the
measured parameter for turning on deicing heaters and

-7-

determining LWC. The heaters indicated at 20 that are associated with the ice detector probe, for removing the ice that has built up on the probe during the operational cycle, may also be activated with this
5   signal. The advantage is that reset times may be faster than current practice of deicing the probe after a set mass of ice has accreted.

In the present invention, the frequency sensing circuit 16 provides an indication of the
10   change of frequency of the probe 12, and this signal is provided to computer 22 that includes a time input to provide a rate of change of frequency determination section 24. The rate of change of frequency (df/dt) is a function of liquid water content, air temperature
15   and airspeed and is determined in a matter of milliseconds during initial ice accretion, and updated continually until the deicing heaters are turned on. The heaters can be turned on at a selected time after an initial df/dt signal, or when df/dt reaches a
20   selected value. The probe heaters remain on long enough to deice the probe after which the cycle repeats. The correlation of the frequency rate change signal to LWC can be provided in a look up table shown at 26, or by entering the parameters into an algorithm
25   in memory section 26A of the computer 22. Based upon temperature and airspeed inputs, and the measured rate of change of frequency over all or a portion of the ice accretion cycle as shown in Figures 2, 3 and 4, the liquid water content (LWC) measurement can be
30   determined.

The look up tables or algorithm reflecting the measured plots include an input of the true air speed 28. For example, an input from a pitot tube, or

-8-

other suitable air speed indicator, that determines the relative velocity of the airflow 18 past the vibrating probe 12 may be used. An additional input parameter is air temperature indicated at 30, which
5   can be obtained from a known total air temperature sensor, or an ambient air temperature sensor, as an input to the look up table 26 or algorithm section 26A.

Air vehicle configuration constants,
10 including for example the aircraft tolerance to ice build up can be an input, as indicated at 27. These factors can insure timely activation, while minimizing nuisance activation, of ice protection equipment, and also can insure a more correct LWC indication.

15 The known relationship of the liquid water content to the rate of change of frequency, air speed and air temperature, and if desired, aircraft configuration constants, then will provide a signal that is a direct, reliable indication of liquid water
20 content (LWC) as indicated at 32. This LWC information can be used for research or analysis of the ambient air. Additionally, the output of the look up table and computer 22 can be utilized for activating the probe heater 20, as shown by a signal
25 along the line 34, and also can then be used for activating and turning on the air vehicle surface deicing heaters indicated at 36 and/or notifying the crew of an icing condition, which comprise one form of ice protection system.

30 Utilizing a vibrating type ice detector, and using known air temperature and airflow velocity, in one plot a temperature of -5°C, and an air velocity of 200 knots, the results at three different levels of

-9-

LWC are plotted in Figure 2. It can be seen that at the known LWC levels of 0.3, 0.75 and 1.2 grams per cubic meter, indicated by the plots 40, 42 and 44, respectively, the rate of change of resonant vibration

5   frequency of the ice detector probe as ice accretes on the detector probe provides an indication of the liquid water content that can be identified quickly. The elapsed time is very short before distinct patterns emerge. For example, within 10,000

10   milliseconds a determination of the rate of change in frequency in Hertz per millisecond can be examined and determined from the plotted data points. At 20,000 milliseconds the data for each LWC merge and the plots are clearly defined. From commencement of accretion

15   to about 5,000 milliseconds the data points run together and are somewhat scattered. The plots or curves are derived using air samples with a known LWC.

All of the liquid water content (LWC) samples used in plotting Figure 2 have a liquid water content that is

20   above the Ludlam Limit at the temperature and airflow rates disclosed.

The heaters for deicing the ice detector probe 12 are turned on at the ends of the plots in Figures 2, 3 and 4. For example, the probe heaters

25   are turned on at the time represented by vertical lines 45 and 46 in Figure 2 for the plots at 0.75 and 1.2 grams per cubic meter, and are turned on at the time shown by vertical line 48 for 0.3 grams per cubic meter. The heater turn on signal is given when the

30   ice has built up on the probe to affect the frequency signal from the probe a desired amount.

Identifiable results are also achievable with a lower ambient air temperature, -10°C, as

-10-

illustrated in Figure 3, and at the same air velocity
of 200 knots. The plots for 0.3, 0.75 and 1.25 grams
per cubic meter are indicated at 50, 52 and 54,
respectively. The measured data points for each LWC
5 merge closely together to define distinct identifiable
plots of df/dt in less than 10,000 milliseconds to
provide an indication of the liquid water content
(LWC), regardless of whether the content is above the
Ludlam Limit. In Figure 3, (-10°C and 200 knots) only
10 .75 and 1.2 g/m³ plots exceed the Ludlam Limit of LWC.

Again, the probe heaters are turned on where
the plots end in Figure 3, generally along a vertical
line 58, for the plots where the LWC is above the
15 Ludlam Limit, namely plots 52 and 54, and a vertical
line 56 for the turning on of the deicing heater on
the vibrating type deicer probe when the LWC is below
the Ludlam Limit, namely 0.30 g/m³.

Figure 4 shows further plots of the rate of
20 change of frequency in hertz per millisecond plotted
against time, in milliseconds. In this case, the
temperature is -5°C and airspeed is 100 knots. While
somewhat more scattered, the data points can be
averaged so that the plots for the liquid water
25 content (LWC) of 0.30 g/m³, is shown at 60. The .30
g/m³ LWC is below the Ludlam Limit while the others are
above the limit. The plot for 0.75 g/m³ is indicated
at 62, and the plot for an LWC of 1.20 g/m³ is
indicated at 64, these plots all show that the rate of
30 change of frequency, df/dt provides sufficient
information to indicate the liquid water content (LWC)
within about 15,000 milliseconds with reliability.
Again, in this instance, the heaters are turned at a

-11-

time indicated by vertical lines 66 and 68 for the plots of 0.75 and 1.20 g/m³, respectively, and the heaters are turned on for the plot for the 0.30 g/m³ at the time line 70.

5   The rate of change of frequency df/dt, will provide information indicating the rate of ice accretion in each of the plots, even though the liquid water content (LWC) may be above the Ludlam Limit. This can provide for early information to the crew of

10   an icing condition and/or activation of the deicing heaters on the air vehicle to avoid any substantial build up of ice. Also, the information on LWC can be used for research and analysis because the present invention gives a reliable indication of liquid water

15   content at substantially all ranges of liquid water content.

Figure 5 is a plot of df/dt averaged data points for different airspeeds to show that there are distinct indications of liquid water content at

20   different air speeds, different liquid water content amounts, and different temperatures such that LWC can be determined reliably.

The points on the plot are derived from an average of approximately 20 data point readings near

25   the ends of the plots for corresponding LWCs shown in Figures 2, 3 and 4, as well as similar data points taken at different airspeeds and temperatures as listed in Figure 5. For example, at a temperature of -5°C, three plots are provided for liquid water

30   contents of 0.3, 0.75 and 1.2 g/m³. Each of these conditions of temperature and known liquid water content were used to determine df/dt of a vibrating probe at airflows of 100, 150 and 200 knots.

-12-

The plot shown at 60 is with 0.30 g/m³ of liquid water at -5°C, and at 100, 150 and 200 knots. The change in rate of change of frequency (df/dt) does not show wide swings, but shows definitive changes

5   between the air flows to indicate liquid water content at particular air speeds and temperature based upon the rate of change of frequency.

Plot 62 represents data points for df/dt at -5°C and 0.75 g/m³ liquid water content, and shows

10   greater changes between the listed air speeds.

The plot 64 is for -5°C with a liquid water content of 1.2 g/m³. Again, the rate of change of frequency provides a distinctive signal at each of the various air speeds to permit direct indication of

15   liquid water content.

At -10°C, the 0.3 g/m³ liquid water content measuring df/dt results in a plot 66; the 0.75 g/m³ LWC results in a plot 68, and the 1.2 g/m³ LWC provides a plot 70. Again, the individual points shown for the

20   plots 60, 62, 64, 66, 68 and 70 are averages of df/dt of data points taken shortly before the heater is turned on, or near the right hand end of the plots of data points shown in Figures 2, 3 and 4.

In aggregate, the plots of Figure 5 show

25   that definitive points are established at each air speed, temperature, and df/dt condition, so that upon determining the rate of change of frequency after a selected time from the start of ice accretion, the liquid water content at a particular temperature and a

30   particular air speed can be determined by a lookup table or by an algorithm. The look up table values can be extrapolated for different airspeeds and temperatures, so knowing df/dt the LWC can be

-13-

determined.   Also df/dt can give the desired
information on when to turn on the heaters.

5   The present invention thus uses readily
available information for providing the liquid water
content (LWC) of airflow past a vibrating type probe
such as an ice detector probe. The determination of
the rate of change of frequency is a straight forward
computation based upon the change in frequency across
a time measurement. The discovery that the rate of

10   change of frequency of a vibrating type ice detector
probe provides reliable indications of liquid water
content (LWC) at substantially all useful ranges of
such liquid water content (LWC) in ambient air permits
enhanced operation of air vehicles in particular,

15   insofar as deicing equipment is concerned, and
enhances the ability to make LWC measurements of
reasonable quality for research purposes.

                The indication of LWC is reliably obtained,
even when the LWC is above the Ludlam Limit.

20   Although the present invention has been
described with reference to preferred embodiments,
workers skilled in the art will recognize that changes
may be made in form and detail without departing from
the spirit and scope of the invention.

-14-

WHAT IS CLAIMED IS:

1.   An apparatus for determining the liquid water content in an airflow, comprising a vibrating probe excitable to vibrate at a resonant frequency which changes as ice accretion occurs, a frequency determination circuit for determining the frequency of vibration of the ice detector probe, and for calculating rate of change of such frequency, and for correlating the rate of change of frequency with inputs including air velocity and air temperature to provide an output indicating liquid water content.

2.   The apparatus of claim 1 including probe deicing heaters connected to receive the output signal for activating the heaters at selected times.

3.   The apparatus of either of claims 1 or 2 wherein the liquid water content is above the Ludlam Limit.

4.   A method of determining liquid water content in an airflow, including providing a vibrating ice detector probe, determining frequency changes indicating ice accretion on the probe, determining the rate of change of frequency of the probe as ice accretes, and providing the rate of change of frequency as an output indicating liquid water content of the air.

5.   The method of claim 4 including the step of initiating heaters on the ice detecting probe after a selected time.

6.   The method of either one of claims 4 or 5 including the step of initiating ice protection systems on an air vehicle on which the probe is mounted.

-15-

7.   The method of either one of claims 4 or 5 including determining liquid water content by providing a measured temperature of the airflow, and the velocity of airflow to a processor including circuit for determining rate of change of frequency.

8.   The method of claim 7 including providing aircraft configuration constants to the processor.

9.   An apparatus for determining the liquid water content of air at a known temperature below the freezing point of water and at a known airspeed, including a vibrating probe excited to a resonant frequency on which supercooled water in the air can freeze and accrete, and a frequency determining circuit connected to the probe to provide an indication of rate of change of frequency of vibration as ice accretes.

10.   The apparatus of claim 9 and a computer to receive the indication of rate of change of frequency of vibration of the probe and to compare the rate of change to values in a look up table to determine liquid water content of the air.

11.   The apparatus of claim 9 and a computer having a memory with an algorithm to receive inputs comprising air temperature and air velocity past the probe and the indication of rate of change of frequency and to provide a value of liquid water content of the air.

12.   The apparatus of any one of claims 9, 10 or 11 wherein the inputs to the computer include aircraft configuration constants.

-16-

13.   The apparatus of any one of claims 9-12 wherein a processor receives inputs indicating air temperature and air velocity at the probe, comprising the known temperature and the known airspeed, and the rate of change of frequency to provide the indication of liquid water content of the air.
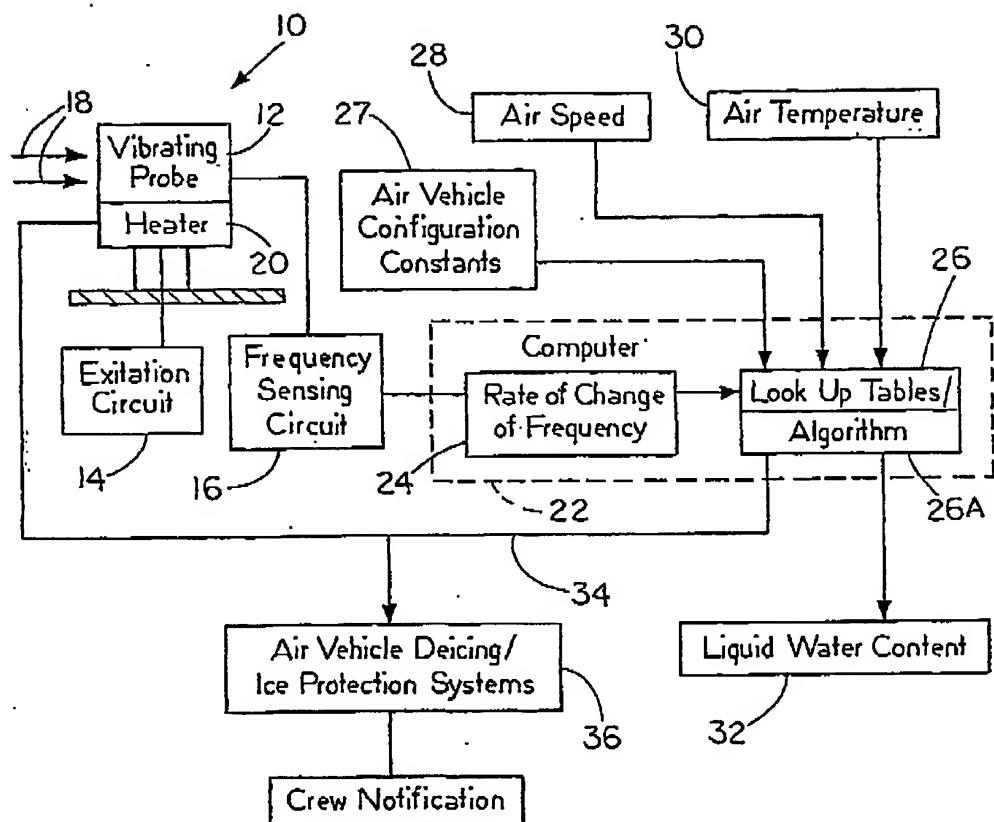
FIG. 1

Figure 2

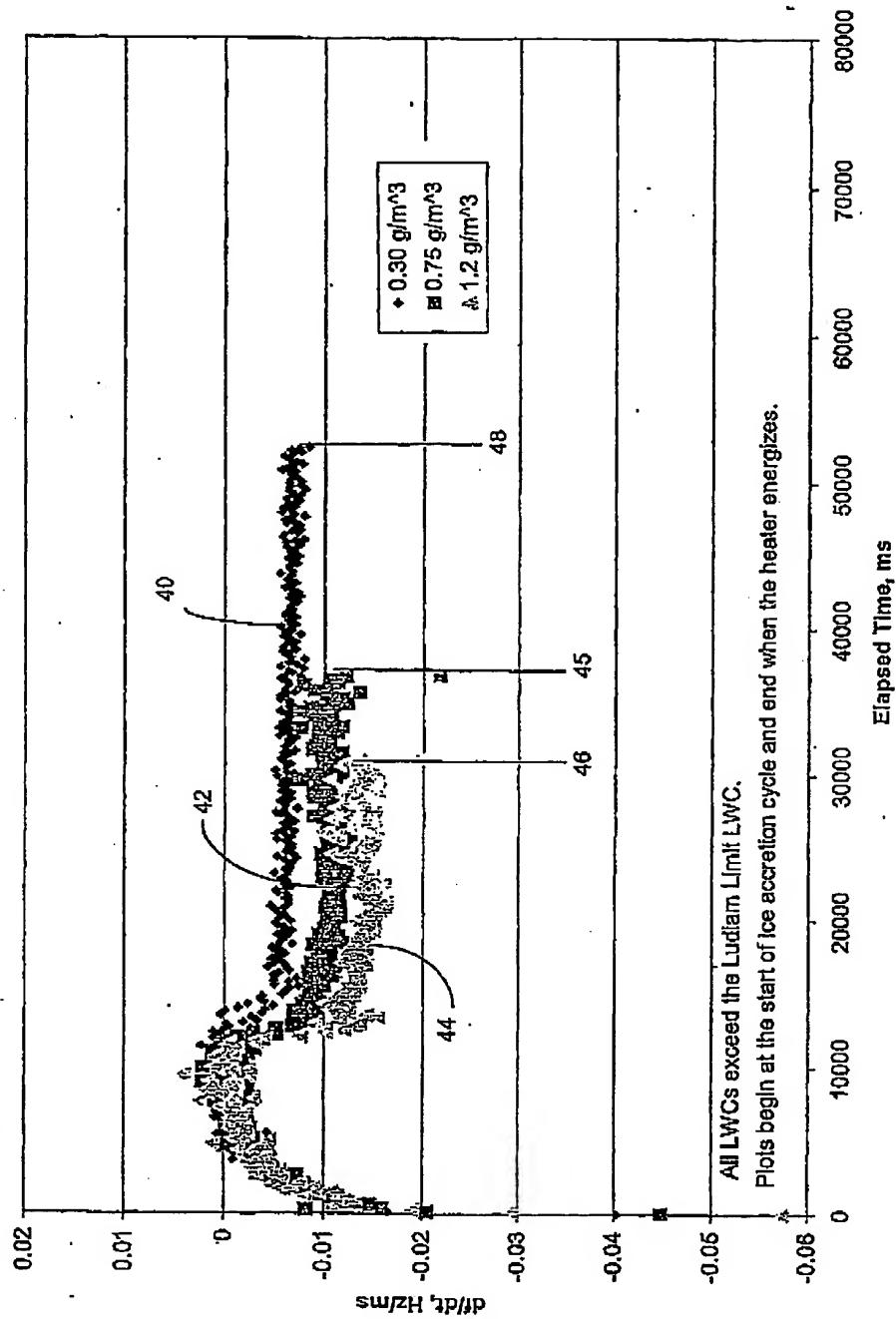df/dt During Ice Accretion at -5°C Ts, 200KTS

All LWCs exceed the Ludlam Limit LWC.
Plots begin at the start of ice accretion cycle and end when the heater energizes.

Figure 3

df/dt During Ice Accretion
-10°C Ts 200KTS

0.75 and 1.20 g/m^3 exceed the Ludiam Limit LWC.

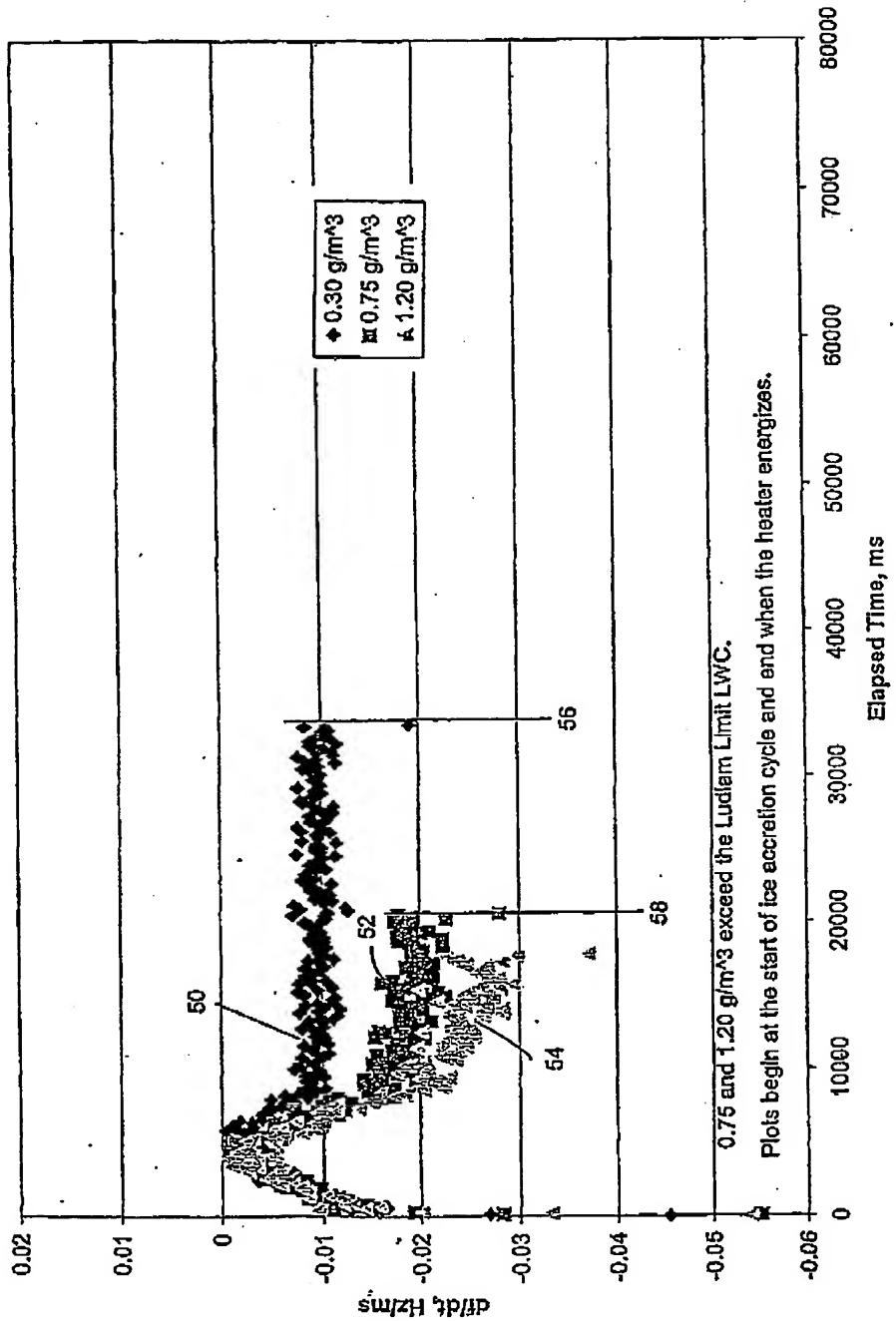Plots begin at the start of ice accretion cycle and and when the heater energizes.
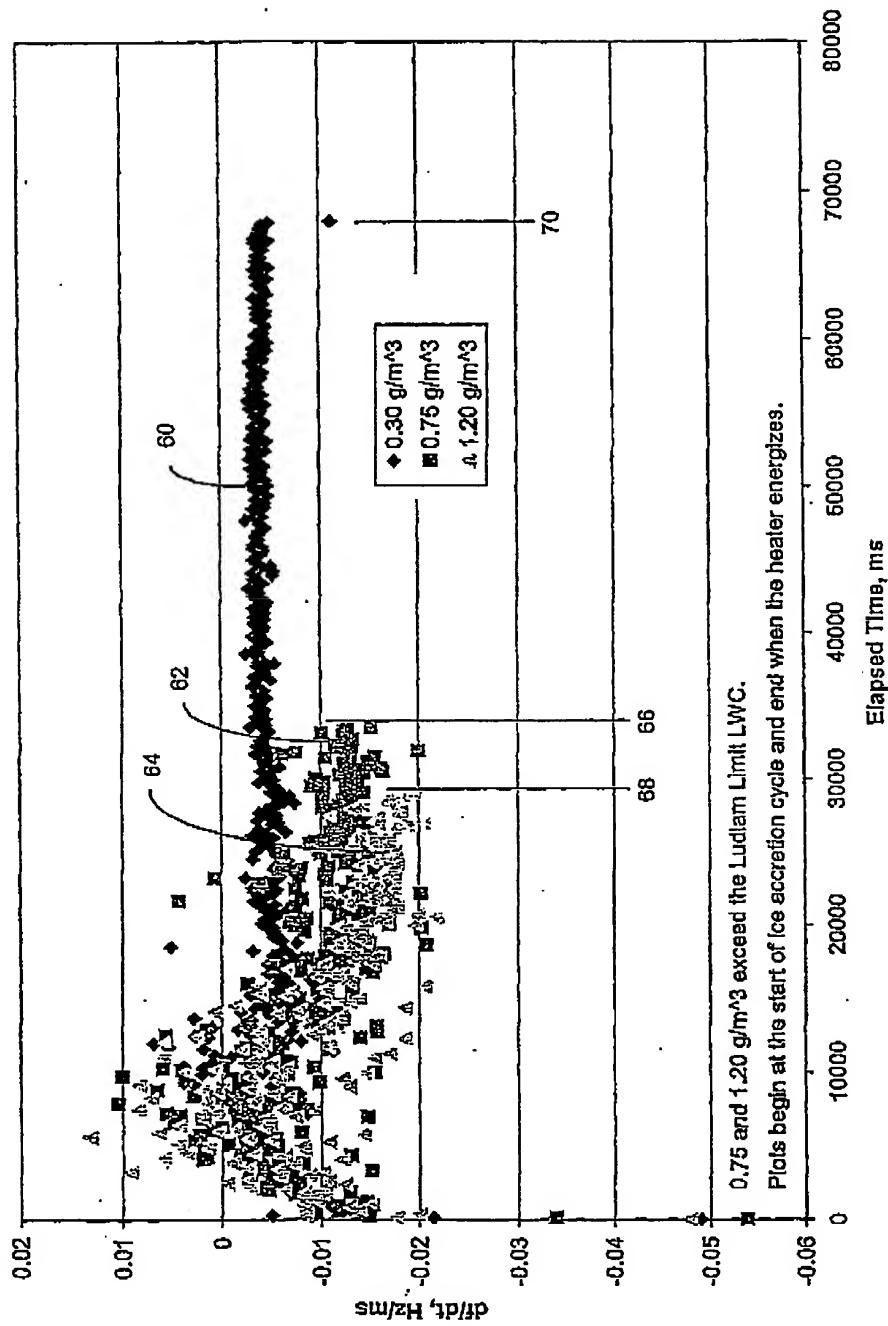
Figure 4

df/dt During Ice Accretion
-5°C Ts, 100KTS

0.75 and 1.20 g/m^3 exceed the Ludlam Limit LWC.
Plots begin at the start of ice accretion cycle and end when the heater energizes.

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   B64D15/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   B64D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, COMPENDEX, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ROY S ET AL: "Smart ice detection systems based on resonant piezoelectric transducers" SENSORS AND ACTUATORS A, ELSEVIER SEQUOIA S.A., LAUSANNE, CH, vol. 69, no. 3, 15 September 1998 (1998-09-15), pages 243-250, XP004140047 ISSN: 0924-4247	1,2,9,11
X	page 248, column 2, line 4 - line 25	4
A	US 4 570 881 A (LUSTENBERGER MARTIN) 18 February 1986 (1986-02-18) column 1, line 29 - line 51	1,4,9
A	US 5 932 806 A (HAMMER JEFFREY MARK ET AL) 3 August 1999 (1999-08-03) column 6, line 5 - line 33	1,4,9

-/--

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 January 2002	09/01/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hauglustaine, H

Form PCT/ISA/210 (second sheet) (July 1992)

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 4570881	A	18-02-1986	CA	1250926 A1	07-03-1989
			CH	656015 A5	30-05-1986
			EP	0229858 A1	29-07-1987
			JP	1845470 C	25-05-1994
			JP	5056831 B	20-08-1993
			JP	62132148 A	15-06-1987
			SU	1521294 A3	07-11-1989
			AT	43731 T	15-06-1989
			DE	3570777 D1	06-07-1989
US 5932806	A	03-08-1999	US	5629485 A	13-05-1997
			AU	4639996 A	03-07-1996
			CA	2206941 A1	20-06-1996
			EP	0797773 A1	01-10-1997
			JP	10510627 T	13-10-1998
			WO	9618894 A1	20-06-1996
EP 0600357	A	08-06-1994	AU	5205793 A	09-06-1994
			CA	2110188 A1	31-05-1994
			CN	1094812 A	09-11-1994
			EP	0600357 A1	08-06-1994
			US	5686841 A	11-11-1997
			ZA	9308891 A	29-05-1995
US 3341835	A	12-09-1967	DE	1573295 A1	09-04-1970
			GB	1087475 A	18-10-1967

Form PCT/ISA/210 (patent family annex) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 600 357 A (RIM TECH INC) 8 June 1994 (1994-06-08) page 3, line 40 -page 4, line 11	1,4,9
A	"ANNOUNCEMENT" AVIATION WEEK AND SPACE TECHNOLOGY, MCGRAW-HILL INC. NEW YORK, US, vol. 142, no. 24, 12 June 1995 (1995-06-12), page 59 XP000510920 ISSN: 0005-2175 the whole document	1
A	US 3 341 835 A (WERNER FRANK D ET AL) 12 September 1967 (1967-09-12) cited in the application the whole document	1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)